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SPECIAL REPORT ON APPLICATION OF SPRAYS CONTAINING DDT BY HELICOPTER

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SUMMARY

1. During the past season a series of tests were conducted to evaluate the helicopter as a means of dispersing aerial sprays of DDT for the control of various agricultural and forect insect pests. The U. S. Coast Guard and the U. S. Navy participated in the project, and several other agencies cooperated in various phases of the work.

2. The Sikorsky helicopter XHNS-1 was used in all tests. Oil solutions of DDT were sprayed from the aircraft by means of a pressure system and nozzles.

3. The control obtained in different tests varied considerably. It is believed that the effectiveness of the treatments could have been improved had it been possible to study the effects of aerological factors and dosage rates.

4. Time studies and observations demonstrated that the helicopter can be used to apply sprays in situations where fixed wing aircraft could not fly safely. However, the limited useful load, limited power, and high maintenance requirements of the XHNS-1 helicopter reduce the net operating time of this model below that which could be expected in airplane spraying.

5. It is concluded that the helicopter aircraft have great possibilities for use both in spraying and survey work. The XHNS-1 model is not considered suitable for such operations, however, because of the limitations mentioned in paragraph 4 and because the purchase price and maintenance costs are economically prohibitive. Practical utilizationof the helicopter in insect and plant disease control will depend on the development of helicopters in which the above disadvantages are eliminated.

6. It is recommended that further test work be carried out as improved models of helicopter are developed. A suggested plan for any future tests is presented.

Introduction

During the early summer of 1945 the Bureau of Entomology and Plant Quarantine, U. S. D. A., the United States Coast Guard, and the United States Navy instituted a cooperative experimental program to test the practicability of a helicopter for aerial spraying of various crops. This program followed the earlier developmental work done with a helicopter at Orlando, Florida on mosquito control with sprays containing DDT. The Florida project was carried on jointly by the United States Coast Guard, the United States Navy and the Bureau of Entomology to evaluate the helicopter for aerial application of sprays to be used by military organizations in mosquito control.

Admiral Robert Donahue, Chief Air Sea Rescue Officer, U.S.C.G. made it possible to obtain a helicopter, equipped for spraying, through Commander A. J. Hesford, U.S.C.G. at Floyd Bennett Field, Brooklyn, New York. Captain T. J. Carter, (MC), USN, Chief of Preventive Medicine, assigned Lieutenant Commander J. S. Yuill, H(S), USNR, to assist in the program. Mr. Yuill was loaned for this work because of his experience in helicopter spray operations at Orlando. D. E. Parker, Bureau of Entomology and Plant Quarantine, acted in a liaison capacity between that Bureau and all cooperators.

The program included tests, falling in several fields of work, of the Bureau of Entomology. The activities also concerned various agricultural organizations in several States in which spray operations were performed. The following list contains the names, with the organizations, of those actively engaged in the spraying operations. It is likely that the list is not complete; the work of others who assisted in the operations is hereby acknowledged. Owners of private properties cooperated in many cases by allowing the work to be done on their properties and crops.

United States Coast Guard

Roy Wagner, AMM 1/c U.S.C.G.R.

Connecticut Agricultural Experiment Station, New Haven, Connecticut

Dr. R. B. Friend, State and Station Entomologist
Mr. Max Zappe
Dr. Neely Turner

New York

Dr. W. A. Rawlins, Cornell University Agricultural Experiment Station, Ithaca, New York
Mr. Howard H. Campbell, County Agricultural Agent, Mineola, New York
Mr. C. T. Williamson, Director, Suffolk County Mosquito Extermination Commission
Dr. H. B. Knapp, Director, State Institute of Agriculture, Farmingdale, Long Island, New York
Dr. Louis Pyenson, State Institute of Agriculture, Farmingdale, Long Island, New York
Dr. J. L. Brann, New York State Agricultural Experiment Station, Poughkeepsie, New York

New Jersey

Mr. Edgar Rex, New Jersey State Department of Agriculture

Bureau of Entomology and Plant Quarantine

Dr. F. C. Bishopp, Assistant Chief of Bureau

Dr. F. C. Craighead, Division of Forest Insect Investigations
Mr. R. C. Brown, Division of Forest Insect Investigations
Mr. J. V. Schaffner, Jr., Division of Forest Insect Investigations
Dr. B. A. Porter, Division of Fruit Insect Investigations
Mr. D. W. Hamilton, Division of Fruit Insect Investigations
Mr. C. H. Hadley, Japanese and Asiatic Beetle Investigations
Mr. E. G. Brewer, Japanese Beetle Control
Mr. N. C. Wilson, Japanese Beetle Control

Equipment

1. The Helicopter

The Sikorsky helicopter, XHNS-1 (Army YR-4) No. 46445, was used in all the test work diseussed in this report. This is the first production model to be manufactured in this country. It is designed primarily as a trainer and is therefore subject to several limitations when used for dispersing insecticides. The following are pertinent descriptive data on this aircraft based on manufacturer's specifications:

1. Airfoils

   a. Main rotor: three blades turning in a horizontal plane to give vertical and translational lift.
   b. Tail rotor: three blades turning in a vertical plane to counteract torque and to serve as a rudder.

2. Engine - 190 h.p., radial, aircooled

3. Maximum vertical ascent - 100 feet (standard sea level conditions)

4. Service ceiling - 14,000 feet (standard sea level conditions)

5. Speed - -15 to +75 m.p.h; normal cruising speed 55 to 60 m.p.h.

6. Cruising range - 2.5 hours (approximately)

7. Fuel consumption - 10 to 12 gallons per hour

8. Weight - 2136 pounds (empty)

9. Load allowances -

Oil 3-1/2 gallons	22.5 lbs.
Fuel, 30 gallons (full tank)	180.0 lbs.
Pilot	200.0 lbs.
Other	104.0 lbs.
	506.5 lbs.

The net useful load was increased from 104 to 200 pounds by removing one seat and reducing the gas load to 15 gallons. However, the weight of the spray apparatus was 67 pounds so that with a full tank of spray (30 gallons) the aircraft was overloaded about 80 pounds. This precluded carrying an observer except when a smaller volume of spray was to be used, a definite disadvantage in experimental work.

Approximately 75 hours of flight were made in carrying out these tests and all flights were made by the same pilot. From his experience it has been possible to establish limitations for safe flight under the conditions in which the tests were carried out. These limitations are similar to those reported for the test work carried out in Florida. The principal restrictions in operation were lack of power in this model helicopter. Running take off rather than vertical ascent was necessary when the wind velocity was low and the helicopter was carrying a full tank of spray. Hovering frequently was impossible over open ground and speeds less than 40 miles per hour were considered unsafe when spraying wooded areas. There was definite loss of altitude in downwind turns. When spraying wooded areas on the lee side of hills or in narrow valleys the pilot had to exercise great concentration and caution because there was not sufficient power to counteract the variable wind currents and down-drafts common to such areas. In some restricted or "tight" locations spraying was done only while flying into the wind. Frequently less than a full tank of spray was carried to reduce the overload. Down wind flight was avoided wherever possible and tight turns at low altitude were not used except under the most favorable conditions.

Mechanical trouble during this test work except for one engine failure was not above that encountered when this model helicopter is used in training or administrative operations. The engine failure occurred during a ferry flight over hilly terrain. The helicopter was carrying a pilot, a passenger, approximately 15 gallons of fuel, but no spray solutions. The initial altitude was 1100 feet above ground. By following standard procedures the pilot was able to effect an autorotative (no power) landing in a small meadow, approximately 75 by 200 feet. The only damage to the helicopter was to one main rotor blade. A new set of blades were obtained the following day and operations resumed the second day after the accident. There were no injuries to pilot or passenger.

During one flight the tension spring on the main pitch control lever failed. The pilot was able to complete the flight by exerting continuous strong pressure on the lever to maintain the proper pitch setting. There were no unusual operation or maintenance problems other than those mentioned above.

2. Spray Apparatus

The spray apparatus consisted of a 30 gallon helicopter fuel tank, a pressure system, and nozzles. The tank was mounted in the cabin just back of and above the pilot's seat. Oil resistant hose

carried the solution from the tank to a large capacity aircraft fuel strainer and thence to an aircraft hydraulic pump mounted on the engine. Metal tubing led from the pump to an adjustable relief valve beside the pilot's seat. From the relief valve a bypass line returned to the tank. The pressure line led to a quick acting shut-off valve, also mounted beside the pilot, and thence to the nozzles. The latter were evenly spaced on a boom nine feet long which was suspended, by a bracket, 18 inches below the feselage and just forward of the tail section. The nozzles (Spraying Systems Co. No. 1/4 TT 8001) had a slotted orifice 0.20 inches in diameter and delivered a flat spray.

In the earlier work carried on in Florida, this apparatus was found to be very satisfactory for atomizing oil solutions of DDT provided the spray material were kept free of sediment. It is more flexible than most aircraft spray equipment in that the fineness of atomization can be controlled within limits by changing the pressure setting on the relief valve or by using coarse or fine spray nozzles. The discharge rate can be changed from 0 to 5.5 gallons per minute by increasing or decreasing the number of nozzles on the boom. In all tests included in this report the operating pressure was 150 pounds per square inch. The discharge rate for 16 nozzles was 5.0 g.p.m. Time and facilities were not available to determine the effective swath width of the deposited spray or the droplet spectrum. However, for a spray solution of similar viscosity used in mosquito control tests in Florida the swath width was 60 feet and the droplet spectrum, based on number of droplets, was 73 per cent below 100 microns in diameter, 96 per cent below 200 microns, 99 percent below 300 microns and 100 per cent below 400 microns.

Prodedure

The spraying program included treatments of a number of plant hosts and insects under conditions that varied considerably. The types of terrain ranged from open salt marshes to wooded areas on steep hillsides: One special operation was performed within an open air stadium at New Haven, Connecticut; the Yale Bowl. Plots to be treated were selected by inspecting the area from the ground and usually were viewed from the air before spraying. When the boundaries of the plots were not clearly designated by roads or natural features of the terrain, artificial markings were placed so as to be visible from the air. Colored cloth flags or white meterological balloons were used; mainly cloth flags. In wooded areas the flags or balloons were placed in the tops of the trees to mark the corners. Neither type of marker is considered entirely satisfactory and considerable time is required in establishing this type of marker in wooded areas.

Since a helicopter does not require an established airfield for landing and take-off it was possible to use service points near each

plot or series of plots in one area. At night, or other times when the helicopter was not in use, it was stored in a hangar at an airfield for security and protection from weather. A service point was established as near the plots as possible in order to reduce ferry distance for refueling and loading with insecticide. Any reasonably level and smooth area free of obstructions for 100 yards was considered suitable. Fuel for the helicopter and spray materials were hauled to the service point by truck. The spray tank was filled by means of an aircraft wobble pump fitted with the necessary pipe and hose.

To aid the pilot in locating the service point or spray plots from the air, smoke candles were used. These proved to be much more satisfactory than wind T's as the smoke not only showed the direction of the wind but also indicated its velocity and the presence of downdrafts.

With the exception of the tests for control of mosquito larvae, all spraying was done during the early morning hours, usually starting at daylight and terminating when the wind velocity exceeded 15 m.p.h, or when convection currents prevented proper settling of the spray. On favorable days operations would be carried on for three to five hours. Flights in rain or hail will damage the rotor blades so no operations were conducted during rainy weather.

The altitude when spraying was 25 to 30 feet above the ground or trees unless obstructions required greater height. Where possible spray patterns were made in both directions across the wind. This results in a more uniform application of the insecticide because the drift tends to distribute the spray more evenly. However, over hilly terrain and in restricted areas it was frequently necessary to make all flight patterns into the wind to obtain maximum lift. In such cases a wide turn was made at the end of each spray swath returning to the downwind side of the plot to start the next swath. The distance between flight swaths was predetermined to obtain the required volume per acre. When the dosage rate was to be one gallon per acre, for example, the required distance between swaths was about 45 feet. In all the spraying, with the exception of plots of potatoes, the pilot spaced the swaths by visual estimate. In spraying the potato plots, however, it was possible for a ground observer to mark the flight lines as the spraying progressed.

The data taken for each spray application are shown on the accompanying form (Figure 1). A ground observer obtained the flight data during th spray operation and the cooperating agency in each case had the responsibility for information on the entomological phases. There were times when the personnel available were insufficient to record complete data.

Results

At the time of writing this report estimates of the control

obtained have not been received from all of the cooperating agencies. Such results as are available are presented in tables 1 and 2.

Table 1 - Test Applications

Date	Locality	Insect	Area Treated Acres	Dosages Lbs.DDT/A.	Control
Host-Apple					
May 22	Conn.	Cankerworm, larvae	5	1 1/	Satisfactory
" "	"	" "	5	2	"
" "	"	" "	5	0.5 2/	No record
May 31	Conn.	17 yr. Cicada, adults	5	3	Unsatisfactory
" "	"	" "	5	2	"
" "	"	" "	5	3	"
Jun 28	New York	Codling moth, larvae	6	1 3/	No record
Aug 3	" "	Codling moth, larvae and pear psylla	12	1	Unsatisfactory
July 11	Conn.	Apple maggot, adults	5	1	No record
Aug 8	"	" "	5	1	No record
Host-Potato					
June 28	New York	Aphis	4	1/2 4/	Unsatisfactory
" "	" "	"	2	1/2 4/	"
" "	" "	"	1	1 4/	"
" "	" "	"	4	1 4/	"
July 3	Conn.	Aphis, leafhopper	10	1	Satisfactory
July 4	"	Fleabeetle, leafhopper	10	1	Satisfactory
" "	"	" "	10	1	Unsatisfactory for leafhopper
" "	"	" "	10	1	"
" "	"	" "	10	1	Marginal
July 11	Conn.	Aphis, leafhopper	20	1	Satisfactory

Table 1 (Cont.)

Date	Locality	Insect	Area Treated Areas	Dosages Lbs.DDT/A.	Control
July 12	Conn.	Fleabeetle, aphis, leafhopper	10	1	Satisfactory
" "	"	" "	15	1	"
" "	"	" "	10	1	Unsatisfactory for fleabeetle
" "	"	" "	10	1	"
" "	"	" "	10	1	"
" "	"	" "	10	1	No record
Aug 8	Conn.	" "	20	1	Satisfactory
Host-Hardwoods					
May 24	Conn.	Cankerworm, larvae	10	2	No record
May 25	"	" "	10	3	Satisfactory
" "	"	" "	10	1	"
" "	"	" "	5	1	"
May 29	"	" "	5	2	"
" "	"	" "	5	8	"
" "	"	" "	5	4	"
May 30	"	Gypsy moth, larvae	5	2.4	No record
June 19	"	" "	5	1	"
" "	"	" "	24	1	"
" "	"	" "	20	1	"
July 11	Conn.	Birch leafminer, adults	5	1	Undetermined
July 13	"	Elm leaf beetle and scolytids, adults	23	2	Leaf beetle - satisfactory; scolytids - no record
Aug 28	Conn.	Striped oakworm, larvae (late instars)	5	1	Unsatisfactory
" "	"	" "	5	0.5 5/	"
" "	"	" "	5	0.25 6/	"
~~Hosts-Pine~~					
May 24	Conn.	Pine bark aphis	5	3	No record

Table 1 (Cont.)

Date	Locality	Insect	Area Treated Acres	Dosages Lbs.DDT/A.	Control
Hosts-Pine					
May 24	Conn.	Pine bark aphis	5	3	No record
June 21	"	European pine shoot moth, pupae, adults	3	1	Unsatisfactory
June 22	"	Sawfly, (D.frutetorum), eggs.pupae,adults	10	1	Satisfactory
Aug 31	"	Sawfly (D.frutetorum), larvae	6	1	"
" "	"	" "	16.5	0.5[5]/	"
" "	"	" "	5	0.25[6]/	Unsatisfactory
" "	"	" "	5	0.13[7]/	"
Aug 22	New Jersey	Sawfly (D.sertifer) adults, emerging after spraying	28	1	"
Mosquito Control					
June 29	New York	Salt marsh spp. larvae	30	0.2[8]/	Unsatisfactory
" "	"	" "	10	0.2[8]/	"
" "	"	" "	200	0.2[8]/	"
July 5	Conn.	Misc. spp.,adults	83	1	Satisfactory
Aug 29	"	" "	49	1	"

Table 1 (Cont.)

Date	Locality	Insect	Area Treated Acres	Dosages lbs. DDT/A	Control
Miscellaneous					
June 21	Conn.	Wild life study	5	2	No injury to birds or fish
Aug 3	New York	Golf course for Japanese beetle, adults	150	0.8	Incomplete record; probably marginal

1/ Unless otherwise indicated the spray mixture consisted of 1 pound DDT in 1 quart xylene and made to 1 gallon with kerosene.

2/ 0.5 pound DDT in 1 quart xylene and made to 1 gallon with kerosene.

3/ 1 pound DDT made to 1 gallon with Shell ACX73

4/ 1 pound DDT in 1 pint Velsicol AR60 and 7 pints Shell ACX54

5/ 0.5 pound DDT made to 1 gallon with kerosene.

6/ 0.25 pound DDT made to 1 gallon with kerosene.

7/ 0.13 pound DDT made to 1 gallon with kerosene.

8/ 5% DDT in 90% Diesel oil and 10% #30 lubricating oil.

Table 2 -- Operational Data 1/

Host Plant	Area Treated	Vol. of Spray	Spray Minutes	Ferry 2/ Minutes	Repairs 3/ Minutes
Apple	43	68	52	46	0
Potato	165	163	115	120	600
Hardwoods	147	256	160	151	[illegible]
Pine	46	56	37	61	0
Mosquito	342	261	147	34	120
Control	743	723	511	412	722
Average		0.97/A.	0.7/A.	0.6/A.	1.0/A

1/ Includes only those applications for which operational data are complete.
2/ Includes only the time to fly from the service point to the plot and return.
3/ Based on the maximum of 5 hours operational time per day; does not include the time required for routine 25 hour checks.

As shown in table 1 there was a great deal of variation in the control obtained. The reasons for poor control are not known in some cases. Because of the number of tests included in the schedule and the varied conditions under which applications were made, it was not possible to determine the extent to which results might have been affected by such factors as dosage rate, fineness of atomization, irregularities in flight pattern and meteorological conditions. The data on the potato plots are more complete than the others and some explanation of results can be made. The poor control of aphis on the New York plots is believed to be due, in part, to the small size and long narrow shape of the plots. Wind drift apparently carried a portion of the spray beyond the plot boundaries. In Connecticut, where the plots were larger, the control of aphis was more effective. The variable control of fleabeetle was probably due to differences in populations of the insect. There was, in most cases, high mortality of the beetles in the plots having dense populations, but in several, reinfestation from adjacent areas soon brought the number back to high levels. Apparently there was not a sufficient residue of DDT deposited to give prolonged protection. The applications for control of mosquito larvae had to be made in the late afternoon rather than at daylight because of unfavorable weather. It is possible, considering previous experience in Florida, that the poor control (about 50 per cent) was due to the presence of convection currents which prevented the finer portion of the atomized spray from reaching the ground. Unfortunately it was not possible to repeat the treatment at daylight or with a coarser spray. The applications for control of adult mosquitoes gave excellent results. The dosage was higher than necessary for immediate kill because it was desired to place a heavy residual deposit in the area to prolong protection.

It is believed that in several instances the unsatisfactory results obtained were not due to poor performance of the helicopter but to improper dosage, too fine atomization of the spray, or resistance of the insect pest to DDT. For example, the seventeen year cicada and the pear psylla apparently are not susceptible to DDT when applied at practical dosage rates. Control of the striped oak worm would probably have been more effective when the larvae were in the earlier instars. Although we do not have a record for the control of gypsy moth, it can be assumed that helicopter sprays would be effective if applied under the proper conditions since others have demonstrated that aerial and ground sprays are satisfactory for controlling this insect. It should be mentioned that failure of the helicopter spraying to affect wildlife (Connecticut, June 21) is not conclusive evidence that the application of two pounds of DDT per acre can be considered safe, for others have shown that applications as low as one half pound per acre may kill fish.

The data in table 2 show that the time required for the different tests varied appreciably. Except for the mosquito control tests most of the plots were twenty acres or less in size. In treating such small areas maximum time efficiency is not obtained. The spray swaths are short, increasing the proportion of the flight time used in making turns between swaths and less than a full tank of spray material is dispersed in each flight increasing the number of trips (ferry time) between the service point and the plots. In contrast, the mosquito control plots, except for one of ten acres, were larger in size and the time efficiency was noticeably higher. In all of these applications, except the ten acre plot, a full tank of spray was carried in each trip and the swath lines were longer. This reduced both the ferry time and the time required in turning between swaths. On the larval control plots the volume applied was only one-half gallon per acre. Had the volume been one gallon per acre, as it was in most of the other plots, the total volume applied would have been 381 gallons instead of 261 gallons in 147 minutes. Three factors are responsible for the high volume per minute indicated for the hardwood plots: (1) there were several plots larger than ten acres in this series; (2) several plots were treated at high dosage rates by immediate retreatment; in other words after the first application on the plot the pilot was flying over familiar terrain, and (3) in general the hardwood plots were in more open situations and less maneuvering was required during spray flights.

As mentioned in footnote 2 of table 2, the ferry time required to fly from the airfield to the service point and return was not included, nor was the time for ferrying from one locality to another. The distances differed so greatly with each operation that no generalizations could be made. For any given situation such ferry time can be estimated with reasonable accuracy if the distance and cruising speed of the aircraft are known. Time lost for repairs was primarily due to the emergency landing described earlier in this report. One day of this time was lost in waiting for parts. If spare parts and repair facilities had been available at all times the total repair time would have been reduced by almost one-half. The time required for routine twenty-five hour maintenance checks (not given in the table) will range from two days for an "A" check to fourteen or more days for a major overhaul. Two checks were made during the spraying operations. One required three days and the other twelve days. Considerably more maintenance is required for present models of helicopter than would be necessary for a light airplane.

In addition to the above information general observations were made on the performance of the helicopter and behavior of the spray. In spite of the limited power in this model it was possible to spray in many restricted or "tight" situations when light airplane operation would have been unsafe. Spraying was done successfully over potato fields near woods and buildings and over forest areas in the lee of steep hills and in narrow valleys. When spraying the Yale

Bowl the pilot was able to fly completely around the interior approximately twenty feet above the seats. This flight, of course, was made with a reduced load of spray material. Because of the ability of the helicopter to fly "low and slow" the plots were easily located from the air and the high maneuverability and the visibility for the pilot made it possible to apply sprays more uniformly than would have been the case in a fixed wing plane assuming both pilots had had the same amount of experience in this type of operation. In this model of helicopter, however, the extreme concentration required in this type of operation and the inherent vibration in the aircraft cause greater fatigue to the pilot than would similar operations in a light airplane. About two hours actual flight should be the maximum at any one time for spray operations. Up to five hours of ferry flight can be made in one day.

The effect of the air flow from the rotors on the spray was observed to be different at different forward speeds. In hovering flight the blast from the main rotor drives the spray down in a nearly vertical column. As the forward speed is increased the column of spray becomes more inclined and wider. At normal cruising speed the spray leaves the nozzles in a horizontal sheet of droplets. The left half of the sheet is broken up by turbulence about two feet behind the nozzles but the right half of the sheet gradually spreads out behind the aircraft. At approximately 100 feet behind the aircraft the spray is subjected to a pronounced down-draft. The force of this down-draft is not violent, however, and it is often obscured by wind or rising air currents. The effect of rising air currents on the spray was particularly noticeable during spraying of some of the hardwood plots on steep hillsides. The fine droplets would remain suspended above the tree tops to such an extent that the pilot was continually flying through a mist of spray. This condition might have been corrected by using a coarser spray had time been available for such experiments.

Only oil solutions of DDT were used in the tests covered in this report. However, a few trials were made in the shop to determine whether other mixtures would damage the pump. It was concluded that oil solutions or emulsions of oil solutions of any oil soluble insecticide or fungicide could be sprayed from this apparatus provided the ingredients would not corrode the pump or cause rapid deterioration of the synthetic rubber seal ring on the pump shaft. Suspensions were not tested but probably could not be used.

The inability to carry an observer at all times and the absence of radio communication were found to be handicaps in carrying out this experimental work. An observer could have (1) operated the spray valve allowing the pilot to give his full attention to maintaining the proper flight pattern, (2) made a more accurate observation of the behavior of the spray, and (3) kept a more accurate time record of the operation. Three-way radio communication between the helicopter, the service point, and the ground observer in the plot would have simplified each operation. A set of hand signals were employed by the pilot and the ground observer for routine procedures but there were always new conditions arising for which such signals

were not adequate.

No data are available from which the cost of helicopter spraying can be determined. All units of this model were made for the armed forces on a decreasing price per unit contract. The price of the later units was in the order of $40,000, many times the price of a fixed wing aircraft having the same net useful load.

Conclusions and Recommendations

On the basis of the information given above and other experience with helicopters, the following conclusions are presented.

1. The helicopter, as a type of aircraft, has the possibility of becoming a highly useful tool in the control of insects and plant diseases. It may be developed for dispersion of sprays or for surveys. The great maneuverability, range of speed, and visibility embodied in this type of aircraft give it the following advantages over fixed wing aircraft:

   a. The helicopter can operate in restricted or tight situations and under conditions of restricted atmospheric visibility in which the operation of fixed wing aircraft would be unsafe.

   b. An established airfield is not required for landing. A small cleared space near the operational area can be used as a service point.

   c. There is probably less hazard in making low altitude flight in a helicopter. The accident rate to date for all models of helicopter has been very low. To the best knowledge of the writers there have been only two which resulted in fatalities.

   d. Flight patterns in spraying operations can be made more uniformly than with fixed wing aircraft. The discharge rate and atomization of the spray can easily be changed for different applications. Change of atomization may prove to be a highly important factor in applications to forests, as there are indications that fine sprays tend to filter through the forest canopy and coarse sprays tend to deposit in the canopy.

2. The XHNS-1 model helicopter, however, is not practical for other than experimental work for the following reasons:

   a. Power is not adequate for carrying a sufficient

load or for obtaining the required maneuverability in restricted situations, particularly in hot, humid weather or at high altitudes.

b. The rotor blades are not suitable for flight through rain or hail. During rainy weather the helicopter must be kept in a hangar to prevent the blades from becoming unbalanced.

c. The twenty-five hour maintenance checks require so much time that it would be difficult to follow an intensive spraying schedule. The cost of maintenance would be too great for commercial operations.

d. The purchase price of this model would be prohibitive for commercial use. A fleet of light airplanes can be bought for the price of one XHNS-1 helicopter.

While the XHNS-1 is not suited for extensive use in the control of insects or plant diseases it should be remembered that the helicopter is a new development. Several manufacturers are engaged in the development of improved models and a model practical for spraying may be evolved in a few years. In view of the potential value of the helicopter for insect control work it is recommended that the Bureau of Entomology and Plant Quarantine keep in touch with future developments. It is suggested that, if cooperative arrangements can be made with the armed forces or manufacturers, further test work be conducted to evaluate promising new models. If further tests are conducted it is recommended that the work be carried out along the following lines:

1. Develop spray apparatus that is simple and can be used to disperse a wide variety of insecticides and fungicides, with various droplet spectra in the range of 50 to 500 microns.

2. Determine the discharge rate and droplet spectra of the sprays and their relation to deposit before undertaking control tests.

3. Limit control studies to a few insects and obtain complete data rather than embarking on a crowded schedule as was done in the program carried on during the past season.

4. Provide facilities for increasing the efficiency of operations including proper ground equipment for handling spray materials and servicing the aircraft. If possible radio communication should be available.

5. Make an evaluation of the helicopter for surveys, reconnaissance and inspection work.

HELICOPTER SPRAY TEST

Test No. II-7

Data by: Schaffner Date 22 June 1945

Insect: Diprion frutetorum Stage Adults, eggs & cocoons Host Plant Red Pine

PLOT: Location Rose Pond, Branford, Connecticut

Size 10 Acres-Irregular Topography Rolling, narrow valley Elevation 100'

Exposure North West Slope Moderate

Type of cover Red pine in plot, surroundings - Farm land and mixed hardwoods

Density Fully stocked with few open areas

AEROLOGY: Wind (a) direction (b) velocity up to 10 m.p.h. Temperature 63°

Humidity 95% Lapse rate 7'-67, 0'-66 Weather High overcast Broken ground fog

INSECTICIDE: Composition 1#DDT, 1qt. xylene ~~gals. kerosene~~ 1 gal. to make Application Rate 1#/A.

APPARATUS: Type 20 800/nozzles Pressure 150#

Discharge 5.0 g.p.m. Other - - -

FLIGHT DATA: Direction N&S-both ways Height 25-30' Speed 50-60 m.p.h.

Swath pattern 45' swath

Ferry base to service point (a) distance none (b) time none

Service at New Haven airport

Ferry service point to plot (a) distance 4 mi. (b) time 5 minutes

Service time 20 minutes Breakdown time 0

Time over plot (a) spraying 3 min. (b) turning 7 minutes

TIME LOG:
0655 lv. New Haven airport
0700 ar. over plot
0702 start spraying
0712 end spraying
0725 ar. airport

RESULTS: Coverage Good

Mortality or control Excellent

Map or other notes on reverse side:

Figure 1 - Form used for recording data

Figure 2. Spraying saltmarsh
(Official photo, U. S. Coast Guard)

Figure 3. Spraying potato field
(Official photo, U. S. Coast Guard)

Figure 4. Spraying orchard
(Official photo, U. S. Coast Guard)

Figure 5. Spraying woodland
(Official photo, U. S. Coast Guard)

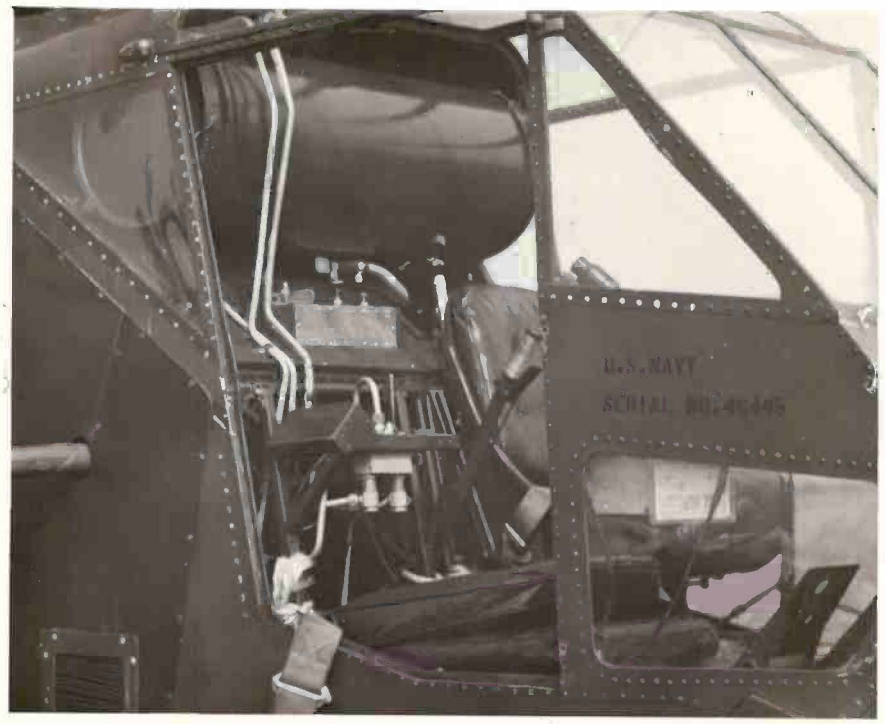

Figure 6. Interior of cabin showing spray tank, relief valve, shutoff valve and lines.

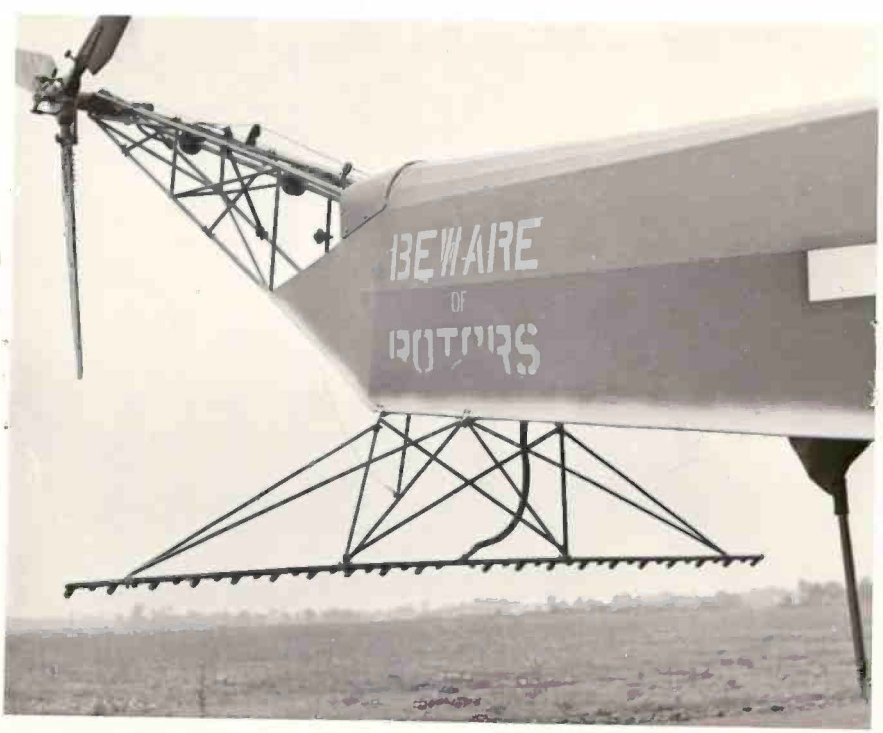

Figure 7. Nozzle boom and bracket.